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AUTHOR Gardner, Judith; Karmel, Bernard Z.
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Preterm Infants' Visual Preferences for Different
Temporal Frequencies

Judith Gardner

Hunter College of the City University of New York

Bernard Z. Karmel

University of Connecticut at Storrs

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Abstract

Preferential looking behavior to stimuli varying in temporal frequency was examined in 11 prematurely born infants when they were between 37 and 39 weeks of postconceptional age. Infants were tested postfeeding on two successive days when they were unswaddled and swaddled. The effects of both stimulus frequency and swaddling were significant. The relationship between amount of looking and frequency yielded a significant linear trend with the fastest frequency (4Hz) being most preferred. The psychophysical function best describing the data was derived. The results were discussed with respect to the possible mechanisms controlling the development of looking at temporally as opposed to spatially varying stimuli.

Preterm Infants' Visual Preferences for Different Temporal Frequencies

Most studies investigating mechanisms of early visual attention have used spatially patterned stimuli varying on such parameters as size of elements, number of elements, number of angles, and contour density. However, stimulus change over time, i.e. temporal patterning, is also a critical aspect of environmental experience, and stimuli varying in temporal frequency have been shown to be potent sources of stimulation attracting the attention of infants (Cohen, 1969; Haith, 1966; Haith, Kessen, & Collins, 1969). Although some studies have investigated infants' responses to systematically varying temporal changes, these studies have typically been either electrophysiological in nature (Ellingson, 1967) or have involved older infants (Karmel, Lester, McCarvill, Brown, & Hofmann, 1977).

Karmel and his associates (Karmel & Maisel, 1975) have suggested that visual attention to spatial and temporal patterns are mediated by mechanisms controlling the synchronization of central nervous system activity elicited by that stimulation. They have shown that the spatially varying stimulus which produces the largest peak-to-peak amplitude of the evoked response (Karmel, Hoffmann, & Fegy, 1974), and the temporally varying stimulus which produces the greatest continuous signal strength in the photically driven EEG (Karmel et al., 1977), also produce the most looking. They have suggested that frequency preference effects are related to the frequency with the most power in the resting EEG at the time of testing. In this respect, they observed that, in three-month-old infants, the 4-6 Hz frequency band both contained the greatest spectral power in the EEG in the occipital region and was most attended.

If, in fact, there are relationships between spatial and temporal stimulus features, synchronization of activity in the central nervous system, spectral density of frequencies in the EEG, and infants' attention, it would be important to establish such relationships as early as possible in development. In so doing, it is reasonable to expect that organismic variables that might affect infants' functional central nervous system organization, as well as stimulus variables known to interact with such organization, would be important. Therefore, age-related changes in central nervous system organization or manipulations that control the internal condition or state of arousal of the infant, could be used to predict preferential looking behavior. One means of manipulating the state of the infant is by swaddling (Lipton, Steinschneider, & Richmond, 1965). Thus, the present study investigated visual preferences of swaddled and unswaddled preterm infants to stimuli varying in temporal frequency. Preterm infants were selected for study because they are at risk for later perceptual and cognitive dysfunction (DeHirsh, Jansky, & Langford, 1966; Drillien, 1972; Lubchenko, Delivoria-Papadopoulos, & Searls, 1972), and many dysfunctional children show deficits in attentional and arousal mechanisms. It is also important to study preterm infants' looking behavior to temporal frequencies because electrophysiological studies indicate that visually evoked responses to temporal change may be useful in assessing high-risk infants (Hrbek, Karlberg, & Olsson, 1973).

Method

Subjects

The subjects were 11 prematurely born infants who were resident in the Neonatal Intensive Care Unit of Jacobi Hospital of the Bronx Municipal Hospital Center. All infants were from either Black or Hispanic families

of primarily lower socioeconomic status. Prematurity was defined as being born at or below 37 weeks of gestational age as estimated by the Dubowitz method (Dubowitz, Dubowitz, & Goldberg, 1970). The infants varied with regard to their age at birth, the basis for their prematurity, and the medical procedures they received while on the Unit. However, at testing, all infants weighed more than 2100 gms, were considered medically stable, and were ready for hospital discharge. Table 1 shows the estimated gestational age at birth, birthweight, postconceptional age and postnatal age at the time of testing, and sex for each infant in the study.

Insert Table 1 about here

These infants were a subset of infants involved in a larger study of the interaction of organismic and stimulus variables on the determination of visual preferences to both spatially and temporally varying stimuli.

Apparatus and Stimuli

The apparatus used was a three-sided looking chamber modeled after one described by Fagan (1970). The back panel of the chamber had a centrally located peephole (.64 cm) and two cutouts (15.2 x 15.2 cm) covered by milk glass. Two sound attenuating boxes affixed to the rear of the panel were used to house photostrobe lamps. Changes in the frequency of illumination were produced by two photostimulators (Grass Model PS2) connected by relays to two waveform and pulse generators (Tektronix Type 162 and Type 161).

The stimuli were light panels varying in frequency of illumination. They had square-wave modulated frequencies of .5, 1, 2, and 4 Hz. Thus, they were presented with equal on and off durations of 1000, 500, 250, and 125 msec, respectively. The luminance level of the stimuli was approximately 9.1 fL.

Procedure

The infants were tested within one hour after feeding on two successive days. On the second day, they were swaddled during testing. Each test session involved the presentation of six pairs of stimuli two times (with right-left position reversed) for 30 sec with an intertrial interval of approximately 30 sec. During testing, infants were seated in a semi-reclining position on the lap of an assistant facing the back panel of the looking chamber. Initiation of stimulus presentation occurred only when infants had their eyes open and were not crying. Duration of fixation at each of the stimuli was recorded by an observer who looked through the centrally located peephole.

Results

As seen in Figure 1, when the data were analyzed with respect to the mean amount of time infants looked at each of the four stimuli, looking increased with increasing frequency for both unswaddled and swaddled conditions, and was generally higher for the infants when they were swaddled than when they were unswaddled (about a 1 sec difference between conditions).

Insert Figure 1 about here

Both of these effects were found to be significant by a swaddling (2) x frequency (4) repeated measures ANOVA; but no interaction between these main effects was found. Examination of the stimulus effect suggested a linear relationship between amount of looking and stimulus frequency, and trend analyses confirmed this impression. There was a significant linear trend when the data from the two swaddling conditions were combined, $F(1,10) = 20.94$, $p < .001$, as well as significant linear trends for each condition separately, $F(1,10) = 5.88$, $p < .04$, for the unswaddled condition;

$F(1,10) = 8.86$, $p < .01$, for the swaddled condition.

We determined the psychophysical function which best described the relationship between amount of looking and stimulus frequency because such a function can be used to construct a regression line against which factors, such as the relationship to other stimuli, the influence of internal condition, or the degree of risk of the infant, can be evaluated quantitatively. To this end, regression analyses were performed with the data transformed using log-log coordinates. Power functions are obtained from the slopes and intercepts of these regression lines. The power function describing the best fitting curve plotted on linear coordinates can be seen in Figure 2.

Insert Figure 2 about here

For both condition combined, the power function thus derived is $R = 9.55(S^{.23})$; where R represents the mean amount of looking, S represents stimulus frequency in Hz, .23 (the slope of the regression line) is the power to which the frequency is raised, and 9.55 (the antilog of the intercept of the response (Y) axis, .98) is the constant.

Discussion

We believe the results of this study are interesting from several perspectives. First, the study showed that a systematic relationship between attention and temporally changing stimuli can be expected as early as 37-39 weeks postconception. Second, this effect appears to be robust, in that few subjects were needed for statistical significance, and the function depicting the preferences appeared to be consistent, at least with respect to the limited changes in state that might occur with swaddling.

Swaddling, as a method to manipulate arousal level, appeared however to show some effect on visual attention at this age. Although we did not find

an interaction between swaddling condition and the particular stimuli used in this study, there did seem to be a tendency for swaddling to have a greater effect on looking behavior with faster frequencies than with slower ones. In a more extensive study, when we manipulated both feeding and swaddling condition, we found an inverse relationship between looking behavior and arousal level such that the greatest amount of looking at stimuli with higher temporal and spatial frequencies occurred when infants were examined after feeding while swaddled (the least aroused condition) as compared to before feeding while unwaddled (the most aroused condition); and an intermediate amount of looking at these stimuli occurred when either feeding or swaddling (not both) was manipulated (Gardner & Turkewitz, submitted). Therefore, we feel that the interaction between external stimulation (temporal frequency) and organismic state (swaddling condition) on attentional behavior might have been demonstrated if a broader range of arousal or stimulus conditions had been used.

Of particular interest to us in this study, however, is the contrast of the present findings with what we might have anticipated from our knowledge of preferential looking at spatial patterns. Studies have shown age-related shifts in preference such that younger infants prefer lower spatial frequencies than do older infants (Brennan, Ames, & Moore, 1966; Fantz & Fagan, 1975; Karmel, 1969, 1974). We thus expected very young infants to show a similar shift toward slower temporal frequencies, assuming the development of preferences to spatial and temporal frequencies is controlled by the same mechanisms. Consequently, because previous studies found that three-month-olds showed the most attention to stimuli between 4 and 6 Hz (Karmel et al., 1977), we assumed that the infants in the present study would most prefer frequencies lower than 4 Hz. We found, however, that infants younger than term age showed a preference

for the highest frequency used in testing (4 Hz), which is in the same range as that preferred by three-month-olds. These preterm infants did not show the expected shift to lower temporal frequencies given younger infants' shifts in attention to lower spatial frequencies as compared to older infants. This preference for the 4 Hz frequency is concordant, however, with studies of infants younger than three weeks showing one dominant frequency in the awake EEG in the 4-7 Hz range (Hagne, Persson, Magnusson, & Petersen, 1973) or the optimal driving of the visually evoked potential in the occipital region by frequencies of about 4 Hz (Ellingson, 1967).

We therefore conclude that the mechanisms controlling the development of looking at spatially as opposed to temporally varying stimuli may not be the same, as their developmental functions do not seem to have the same time course. Response to spatial patterns undergoes a dramatic shift at about two months of age (Maisel & Karmel, 1978; McCarvill & Karmel, 1976; Ruff & Turkewitz, 1979). These shifts in spatial preference are suspected to relate to the development of contrast sensitive neurons in the occipital cortex. Prior to two months, spatial preferences may be controlled by subcortical systems whereas after two months, preferences are probably dominated by cortical systems (Bronson, 1974; Hoffmann, 1978; Woodruff, 1978). That there do not appear to be dramatic changes in attention to temporal frequency over the first three months suggests control by a stable mechanism present at birth. Numerous studies of anatomical, electrophysiological, and behavioral development, as well as those of arousal and attention, appear to support the view that this mechanism is subcortical. Because subcortical systems generally mature earlier than cortical ones, less of a change during infancy in those behaviors which remain under subcortical control would be expected.

It therefore seems likely that responding to both spatial and temporal frequency is controlled subcortically by very young infants. Responding to temporal stimuli may continue to be controlled subcortically, whereas responding to spatial stimuli may shift so that after about two months of age, it comes under predominant cortical control.

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Table 1
Characteristics of the Infants

EGA ^a	BW ^b	PCA ^c	PNA ^d	Sex
31	1530	38.0	7.0	F
32	1900	37.0	5.0	F
32	1920	37.5	5.5	F
33	1780	36.5	3.5	M
33	1600	37.0	4.0	F
34	1890	36.0	2.0	M
34	1900	37.0	3.0	M
35	1850	37.5	2.5	F
36	1860	38.5	2.5	F
37	1850	38.5	1.5	M
37	1860	39.0	2.0	M

Note. All ages are given in weeks.

^aEstimated gestational age at birth

^bBirthweight in grams

^cPostconceptional age at testing

^dPostnatal age at testing

Figure Captions

Figure 1. The mean amount of time infants spent looking at each stimulus when unswaddled and swaddled.

Figure 2. Best fitting curves for data in Figure 1 replotted as power functions; that is, mean looking time as a function of frequency in $\text{Hz}^{-.23}$. Data points are for observed means (X = Unswaddled, ● = Swaddled).



